Transportation Synthesis Report

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GPS in Construction Staking

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Transportation Synthesis Reports are brief summaries of currently available information on topics of interest to WisDOT technical staff. Online and print sources for TSRs include NCHRP and other TRB programs, AASHTO, the research and practices of other transportation agencies, and related academic and industry research. Internet hyperlinks in TSRs are active at the time of publication, but changes on the host server can make them obsolete.

Request for Report

The Construction and Materials Support Center at the University of Wisconsin–Madison requested a synthesis of current practices in the use of Global Positioning System technologies in highway construction, with a focus on contemporary uses of GPS in surveying and staking of projects and the use of GPS for control of grading and paving equipment.

Summary

GPS has been used in construction applications for roughly four years by a handful of states around the country. Early uses that continue today are in survey **Staking**, the marking of sites for grade alignment or width and height of highway beds, and in grading retention ponds. Since the construction season of 2003, Minnesota and Maine and possibly other states have had contractors use GPS in machine control of graders working on highway beds, but only in **Rough Grading**, the cutting of the top layer of soil in preparation for laying down aggregate.

At this time, it appears that GPS technology is not well enough developed for fine grading or paving. The essential problem is one of accuracy. Typically, state transportation agencies maintain construction specifications requiring width and height or depth tolerances to the tenths of one foot, and often to the hundredths. GPS can meet horizontal tolerances in the low hundredths of one foot, but vertical axis tolerances remain at the tenths and rarely prove sufficient to the sophisticated tolerances for vertical characteristics required by most state specifications. Signal consistency also impedes use of GPS in finer applications; in certain less precise operations, such as grade cutting, interruptions in signal need not stop work. A final pass of fine grading will catch any errors in rough grading.

Implementation has largely been a matter of allowing contractors to use GPS at their discretion; in only a few cases—Oregon, in this report—have special technical requirements been employed to govern GPS use. Otherwise, states generally avoid developing GPS-related specifications. Instead, they simply rely on contractors to meet standards; if they do so using GPS, most agencies have no objection. This keeps the responsibility for compliance squarely on the shoulders of industry, and maintains technical pressure on manufacturers to continue to hone and refine machine-control applications of GPS for highway construction.

State agency Web sites offer little direction on the state of the practice. As a result, our synthesis relied almost entirely on direct communication with engineers familiar with the practice. We organize our report with each entry addressing **Uses** of GPS in highway construction, **Benefits** experienced or expected with GPS use, **Implementation** processes employed by each agency, and **Challenges** identified in using GPS in highway construction. When available, we also offer links to **Documents**, and in each case at least one **Contact**. We begin with **TRB** because in conversations with a key committee chairman, Curtis Clabaugh of Wyoming DOT, we were able to identify key uses and challenges of GPS in highway construction. We then look to the states of **Minnesota**, **Maine**, and **Oregon** for their expertise, and finally offer contacts at the state agencies in **New York** and **Washington** that have knowledge of highway construction applications for GPS.

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Curtis Clabaugh, Photogrammetry and Surveys Engineer of Wyoming DOT, chairs the TRB committee with the most expertise on GPS in construction applications—the Committee on Geospatial Data Acquisition Technologies in Design and Construction (AFB80) (http://trb.org/directory/comm_detail.asp?id=1313). An advocate of GPS in transportation infrastructure use, Clabaugh believes GPS to be limited in machine control at this time.

Uses. Rough grading and survey staking only. Vertical control is not yet sophisticated enough to meet highway construction specifications for height of grade or pavement.

Benefits. Reduces work force needs for contractors, and can be accurate if used with supplemental technology.

Implementation. Clabaugh highly recommends no change in specifications. Contractors can use GPS, and agencies can recommend or restrict use, but specifications should not be changed to meet technical capacity of GPS in machine control.

Challenges. Clabaugh sees a number of areas in need of refinement before GPS can be used for machine control in fine grading and paving.

- Vertical control. GPS works well at horizontal control tolerances, but at this point has limited application on vertical axes, because it works in error margins of about one-tenth of one foot, too crude for grading. Combined with laser guidance, however, it seems to work at satisfactory accuracy for vertical control.
- Multiple sources of error. Currently GPS error margins must be accommodated in several areas that affect construction work. Errors can originate in GPS control networks, in GPS mapping data, and in design as well. These error margins may then combine with errors in carrying out the actual construction or grading, making it difficult to meet specifications.
- Signal variability. Atmospheric disturbances, such as from solar flares, are common and one source of disruption of GPS signals. In rough grading this is not a problem, but in fine grading or paving these disturbances could cause significant and frequent work interruption and quality variability.

Wyoming DOT. Clabaugh says Wyoming DOT allows contractors to use GPS in grading, and some do, but it is not an officially sanctioned technology for grading, and the state does not have formal specifications for GPS use in grading or other construction applications.

NCHRP. Referred to widely, a 1998 synthesis report on the use of GPS in surveying and construction control was an early effort in developing highway construction uses for GPS. See the abstract for *NCHRP Synthesis Report 258: Applications of GPS for Surveying and Other Position Needs in Departments of Transportation*, http://trb.org/news/blurb_detail.asp?id=3299. A hard copy is available in the WisDOT Library.

Contacts. Curtis Clabaugh, Wyoming DOT, curtis.clabaugh@dot.state.wy.us or 307.777.4086. Tom Palmerlee, TRB Representative, tpalmerlee@nas.edu or 202.334.2907.

Minnesota

Mn/DOT has been using GPS for grading for two seasons, starting in 2003 with GPS in machine control for grading highways; in grading retention ponds, GPS has been used in machine control in Minnesota for four years. GPS in machine control was spearheaded by case officer Lou (Louise) Barrett.

Uses. Staking, in which surveyors use GPS to lay out the highway course and grading height. Rough grading, mostly in cutting grades at the top of the sand or clay layer, for placing aggregate over it. Also in retention pond grading.

Benefits. Contractors use it because they get an increase in productivity, and because it mediates the loss of grading expertise in a changing workforce. It also shortens the time between grade preparation and finishing the final cut.

Implementation. Left to contractors. Kept specifications the same; merely suggested GPS could be used on certain sites. As long as projects meet tolerances, the tools used are up to them. Current grade tolerances allow a margin of 0.05 feet high and 0.10 feet low.

Challenges. Signals are not constant; some loss in signal is expected daily. Mn/DOT recommends using multiple signal receivers. This variability in signal makes use in finer processes like fine grading and paving impractical at

this time, because interruption can be particularly difficult to negotiate in these processes. Furthermore, difficulty with vertical tolerances can increase the challenge of paving and fine grading with GPS control.

Documents and Web Sites. Mn/DOT keeps a Web page devoted to GPS in machine control; it includes contact information, Q&A on ways in which projects are rated as suitable for GPS machine control, and links to various industry documents, some of which are highlighted below. See http://www.dot.state.mn.us/tecsup/caes/machine.html.

- This industry-sourced article offers details on tolerances and ways to enhance accuracy. See http://www.dot.state.mn.us/tecsup/caes/files/pdf/const_bulletin_ic_site_08_05.pdf.
- See also a construction industry report on GPS and highway grading in Minnesota at http://www.dot.state.mn.us/tecsup/caes/files/pdf/enr_3d_grade_control_10_05.pdf. Note the optimistic tone and the suggestion of special specifications for contractors that use GPS, which seems to overstate its current viability and level of acceptance by Mn/DOT.
- In this brief collection of images, GPS is used with a backhoe working on Minnesota trunk highway 64, by Frontier Construction. The equipment in use is by Trimble. http://www.dot.state.mn.us/tecsup/caes/files/pdf/th64.pdf.

Contacts. Michael Leegard, Mn/DOT Construction Claims and Support Engineer, mike.leegard@state.mn.us or 651.296.0860. Louise Barrett, Mn/DOT Case Officer, lou.barrett@state.mn.us or 651.296.3070.

Maine

Contractors for Maine DOT have been using GPS in machine control and in staking for four years. It is used mainly for aligning grading tracks and for rough grade elevation. It is typically used on bulldozers in grading, but is not used in paving.

Uses. Rough grading, in which GPS is used in machine control for aligning grading equipment and for rough grade elevation. Staking, by which surveyors direct grading paths and heights.

Benefits. Workforce reduction due to automation.

Implementation. Maine DOT has not altered its specifications for contractors using GPS for machine control.

Challenges. Use in fine grading and paving is not yet practical due to accuracy concerns. However, contractors remain interested in such uses, and the technology may develop.

Contact. Tim Lesiege, Photogrammetry and Control, Maine DOT, tim.lesiege@maine.gov or 207.624.3493.

Oregon

Currently ODOT is revising standards for GPS use and is creating a new survey manual. As a result, detailed documentation is not yet available online.

Uses. Staking by surveyors for directing graders. Bulk excavation, or rough grading, but not fine grading at this point.

Benefits. Workforce reduction due to automation.

Implementation. ODOT allows use of GPS; when used, construction contracts include technical requirements, like the use of dual-frequency receivers to mitigate signal loss. Originally, such practices developed because GPS was used by contractors in ways recommended by manufacturers, but not in ways that best suited ODOT purposes, and so technical requirements were created.

Challenges. Accuracy remains the main challenge in grading use.

Documents. See the technical paper *Global Positioning System (GPS) Inventory Standards: Standards and Techniques for Collecting Resource Grade Field Data from a moving vehicle using Trimble Pro-XRS GPS Equipment*, http://egov.oregon.gov/ODOT/TD/TDATA/rics/docs/gps_standards.pdf.
This 2001 document explains how to install and use GPS in grading equipment.

Contact. Ranvir Singh, ranvir.singh@odot.state.or.us or 503.986.3033.

Other State Agencies

The following states were recommended for their use of GPS in construction, but full details were unavailable.

New York. According to Lou Barrett of Mn/DOT, New York has been using GPS in grading for a couple of years. She recommended contacting NYSDOT engineer Dan Streett at dstreett@dot.state.ny.us.

Washington. According to Kurt Iverson, a WSDOT engineer in the agency's Geodetic Survey section, contractors do use GPS in staking and rough grading. However, efforts to fully coordinate these systems with the GIS/GPS systems in development by WSDOT are ongoing. Evidently, lasers are used for leveling grades worked by GPS machine-controlled equipment. Kurt Iverson, iversok@wsdot.wa.gov or 360.709.5532.